Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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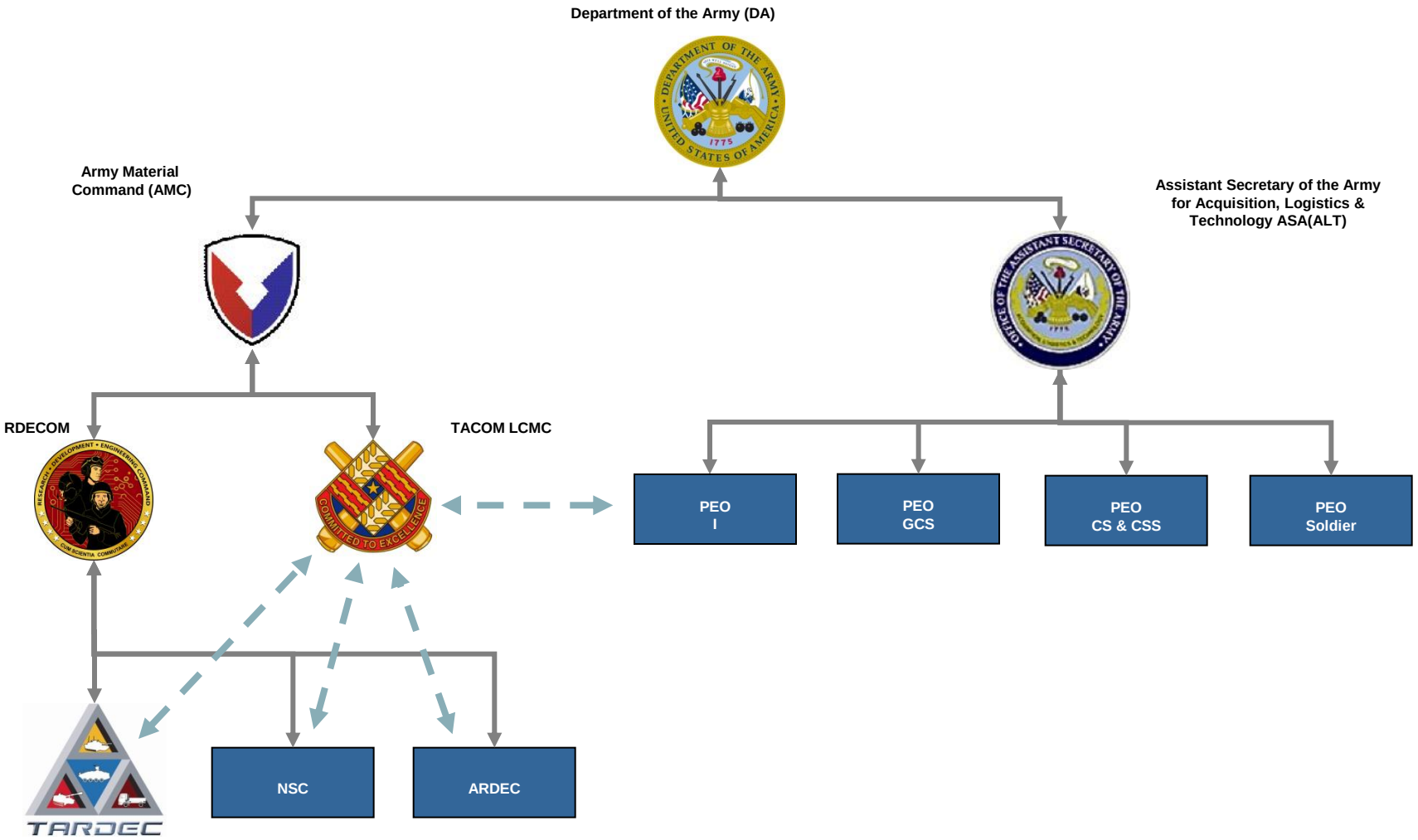
Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis



Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

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TARDEC

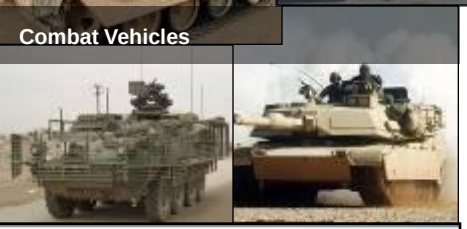

Combat Vehicles


Heavy Tactical Vehicle


Medium Tactical Vehicle


Light Tactical Vehicle


Countermine Equipment



MISSION: *Provide full service life cycle engineering support to our TACOM LCMC customers (PEO GCS, PEO CS&CSS) and to develop and integrate the right technology solutions to the effectiveness for the current force and realize the superior capability of the future force to facilitate army transformation.*


Trailers

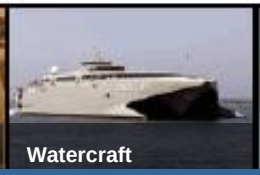

Military Bridging

VISION: *Be the first choice of technology and engineering expertise for ground vehicle systems and support equipment - today and tomorrow.*


Water Generation and Purification


Fuel and Water Storage& Distribution Quality Surveillance Equipment


Logistics Equipment


Watercraft

TARDEC is responsible for research, development and engineering support to more than **2800** Army systems and many of the Army's and DoD's top joint warfighter development programs:

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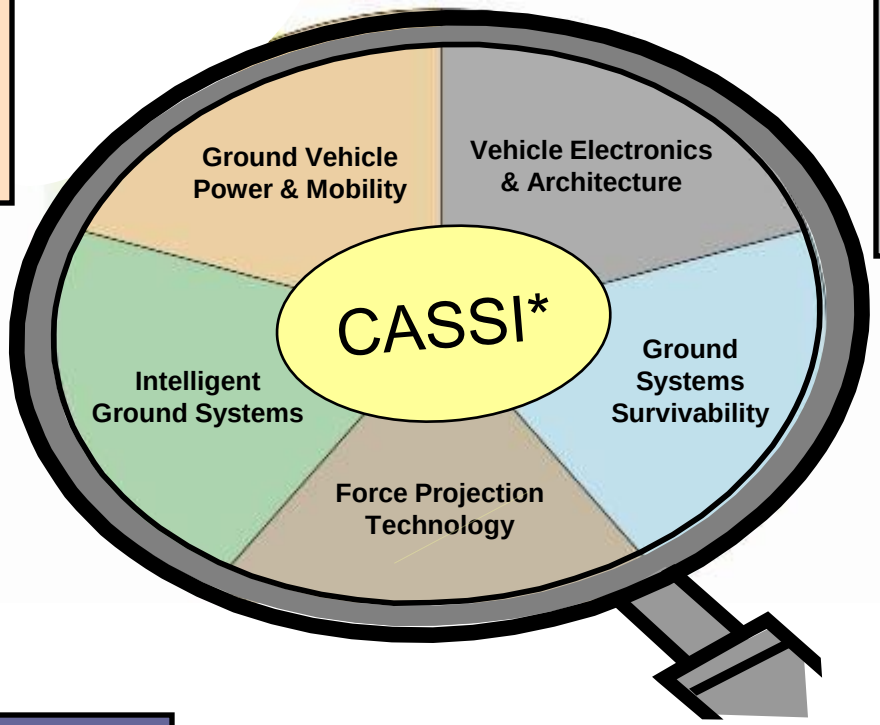
TARDEC

Ground Vehicle Power & Mobility

- Hybrid Electric
- Pulse Power
- Engines
- Fuel Cells
- Suspension
- Tracks

Vehicle Electronics & Architecture

- Power Architecture/Management
- Electronics Integration
- Data Architecture
- Condition Based Maintenance (CBM)
- Diagnostics/Prognostics



Intelligent Ground Systems

- Robotic Systems Technology
- Human-Robot Interaction
- Crew Interface and Automation
- Robotic Follower ATD

Ground System Survivability

- Active Defense
- Signature Management
- Laser Vision Protection
- Ballistic Protection
- Crew Survivability

Force Projection Technology

- Water Generation & Purification
- Petroleum, Oils & Lubricants
- Mechanical Countermine
- Combat Engineering/Bridging
- Gap Crossing
- Future Truck System

* **C**oncepts, **A**nalysis, **S**ystem **S**imulation & **I**ntegration

- Requirements Capture, Concept Development, Program Formulation
- Dynamic/Structural Performance, Mathematical Modeling, Data Analysis
- Physical Validation, Systems-Level Validation
- High Performance Computing, Product & Program Data Management
- Integrated System-Level Demonstrators

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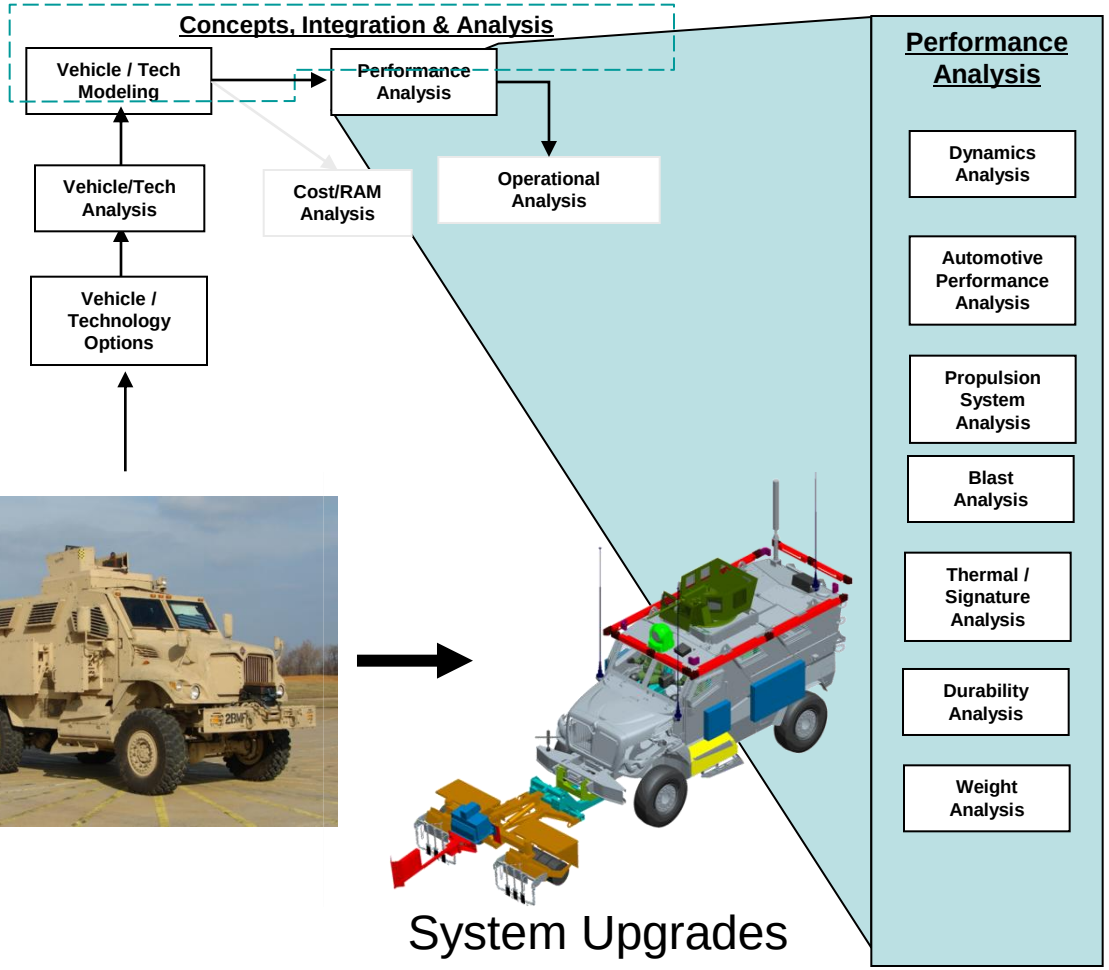
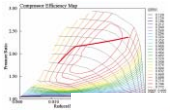
HPC / Tools

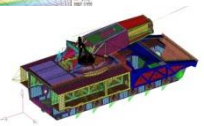


Dynamics Analysis …

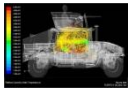
Powertrain Analysis…



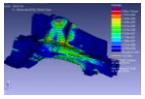
Crash Analysis…….



Thermal Analysis….



Structural Analysis…….



CAD …….

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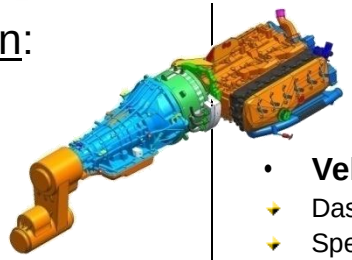
Analytical Tool Description:



Complex Analyses - Primary Modeling Software

- Driveline Components
- Alternative Power Plants
  - Battery, Fuel Cell, Motor/Gen
- Controls
- Expert Systems _ Automated Design of Experiments

VPSET – Vehicle Propulsion System Evaluation Tool

- Developed by TARDEC and Industry Partners
- Government Owned
- Ideal for SSEB Evaluations
- Quick Evaluation of Multiple Platforms and Architectures
- Scalable components

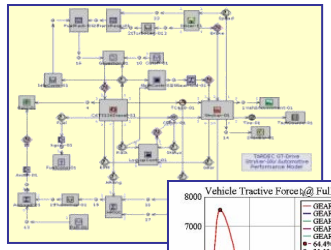
Potential Analysis Projects:

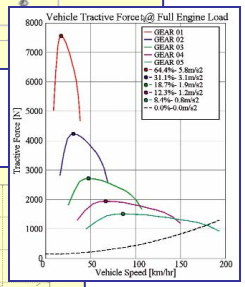
- **Vehicle Upgrade Evaluations**
  - Dash Speed
  - Speed on Grade
  - Step Climb
  - Drawbar Pull
  - Fuel Economy
  - Range
  - Cooling
  - Quantify on/off road mobility
- **Acquisition Support**
  - Virtual Tech Demonstrators
  - CDD -> Automotive Performance Req'ts
  - Section C, L & M M&S RFP Language
  - SSEBs

Analysis Inputs/Outputs:

Inputs:

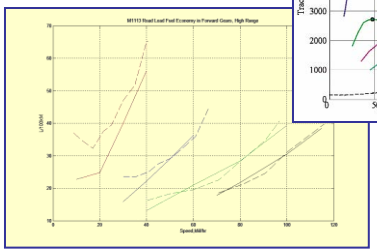
- Engine Torque/Horsepower
- Engine Fuel Map
- Engine Friction/Motoring
- Torque Converter
- Shift Schedule
- Transmission/Driveline Efficiencies
- Accessory Loads
- Mass/Inertia Properties





Outputs:

- Automotive Performance



Recent Analysis:

Propulsion System Models

- Bradley – Power Pack Upgrade
- Paladin – Bradley Power Pack Inserti
- MRAP – Weight and Accessory Load
- Abrams (Full Throttle Performance)
- Stryker
- Joint Light Tactical Vehicle
- FMTV
- HMMWV

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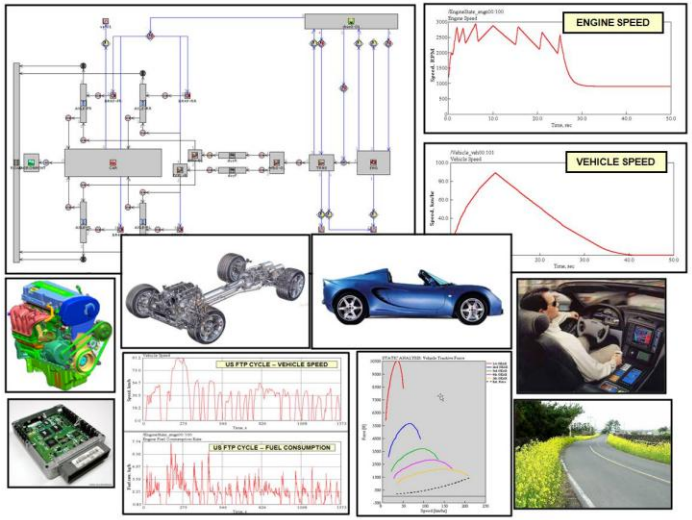
GT SUITE - Vehicle and Driveline Simulation



Commercial Tool

Engine: map-based (general maps w/ scattered data) or higher-level models.
Torque converter: capacity factor/coeff. of perf., torque ratio, lockup clutch
Clutch: actuator, max. torque; “bristle” friction-based model, lockup
Transmission: discrete or CVT, inertias, efficiency, friction, shift strategies
Driveshaft: rigid or flexible
Differential, transfer case: Ratios, inertia, efficiency, friction
Planetary: ratios, inertias, friction
Axles: Inertias, friction
Brakes: actuator, torque map or friction-based model (like clutch)
Vehicle: drag, lift , suspension and load distribution to axles
Tire: radius, rolling resistance, rigid or slipping tire (traction) model
Road: variable grade or elevation, curvature, rolling resistance and traction
Vehicle Driver: accelerator, brake, shift base controls and shifting behavior
Event Manager: user-friendly time, distance or event-based scheduling of successive driving events

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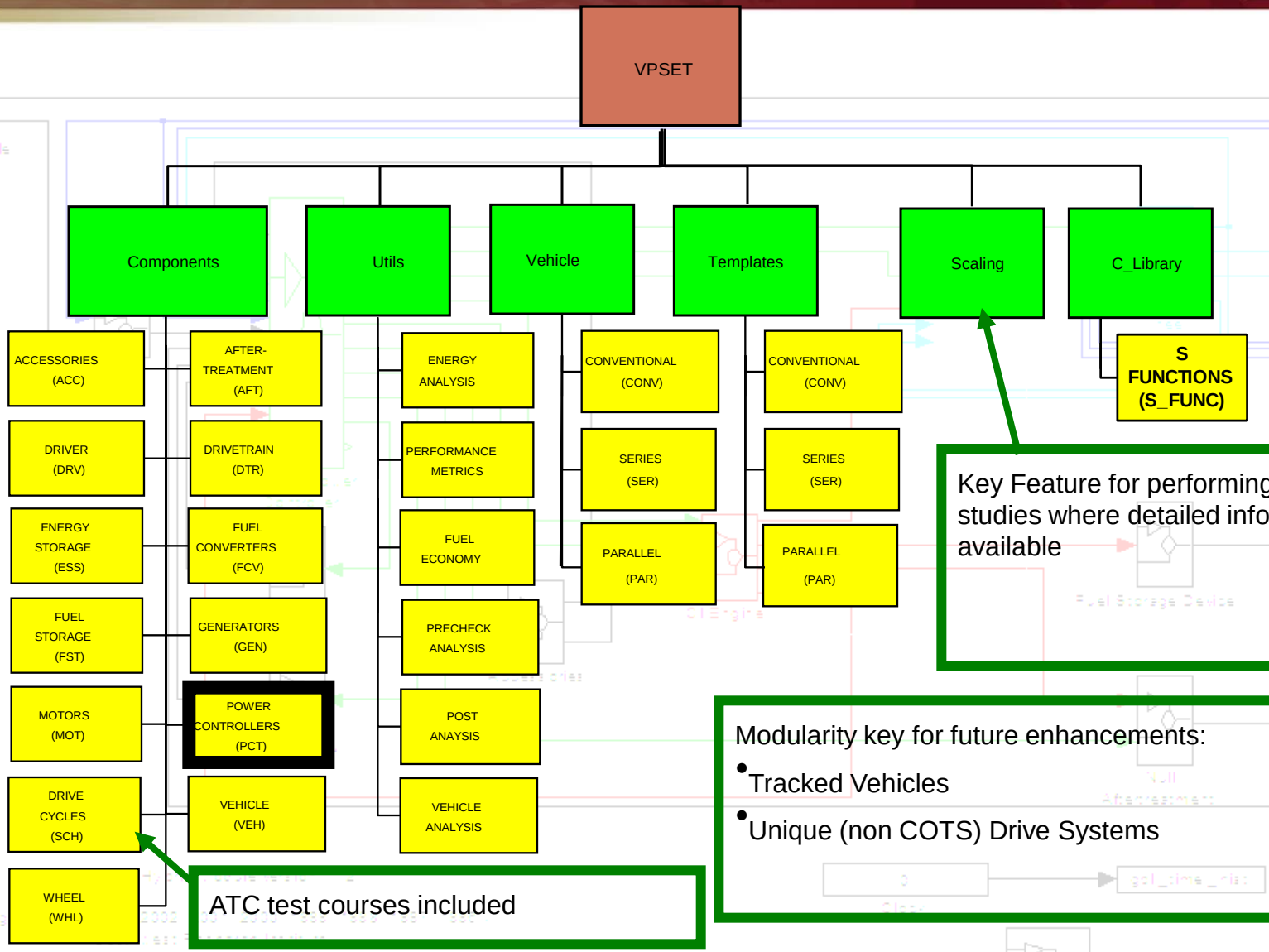

Key Feature for performing trade studies where detailed information not available

Modularity key for future enhancements:

- Tracked Vehicles
- Unique (non COTS) Drive Systems

ATC test courses included

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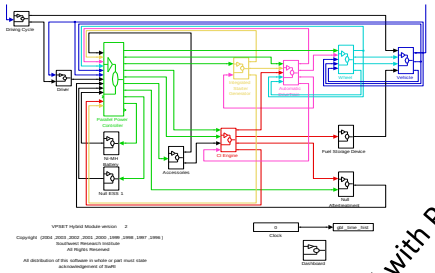
Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

- Goal: Establish a standard for propulsion system analysis for Army vehicle system acquisitions
- Automotive performance analysis and fuel economy prediction
- Evaluation of multiple platforms and architectures (*conventional, parallel, series*)
- Realistic ???



Bidders & Subs

- Design
- In-House Analysis
- Internal M&S Processes
- Propulsion System Models

Convert

Verify Results

VPSET Model

Input Data

Submit Model with Proposal

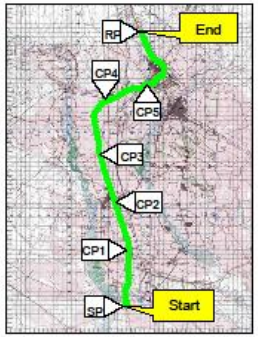
Source Selection Evaluation Board (SSEB)

- Verify input and results
- Evaluate Performance Prediction and Risk to meet Requirements
- Time Savings
- Clarity for Evaluators and KTRs

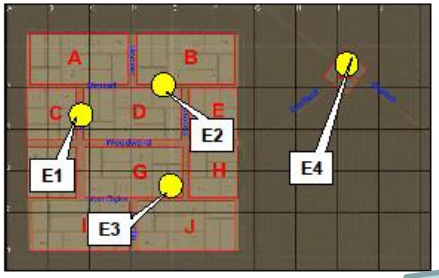
Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

TARDEC Duty Cycle Experiments

Convoy Escort
Example



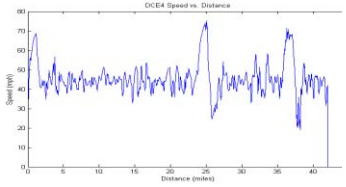
Urban Patrol
Example

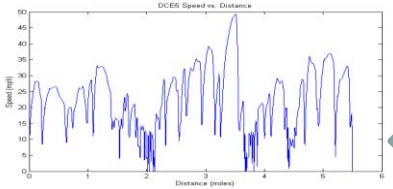


Future Vehicle Model
Predict Automotive Performance

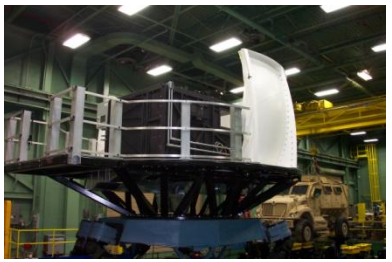
Model Integrated with Motion Simulator
Realistic Motion Feedback to Crew

Duty Cycles Defined
Used for Design and Optimization





Warfighter-in-Loop
Crew Executes Mission



Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

Fuel/Energy Efficiency Requirement Samples

- The JLTV shall meet a fuel efficiency of 60(T), 90(O), ton-miles per gallon based on maximum GVW, including armor. Fuel efficiency will be measured over the Munson Standard Fuel Consumption course per TOP 2.2.603.

- The GCV IFV, with Level 2 armor, using standard JP8 fuel, shall have a fuel consumption at or better than identified for a specific platform weight in the table in 3.1.2.1.3.3.2 when evaluated at sustained speeds of thirty (30) mph on primary roads while providing power at 45KW sustained loads. (T=O)

- The MPC shall achieve 70 (T), 90(O), ton-miles per gallon measured at GVWR over the Munson Combo Fuel Cycle consisting of the Munson28 and Munson14 fuel course cycle run back to back.

Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

- Mission Profile
  - Wartime xx/xx/xx Primary/Secondary/Trails
    - 20 Hour Duration; x hrs moving/ x hrs Idle
  - Peacetime xx/xx/xx Primary/Secondary/Trails
    - 20 Hour Duration; x hrs moving/ x hr Idle

Combined Drive Cycle

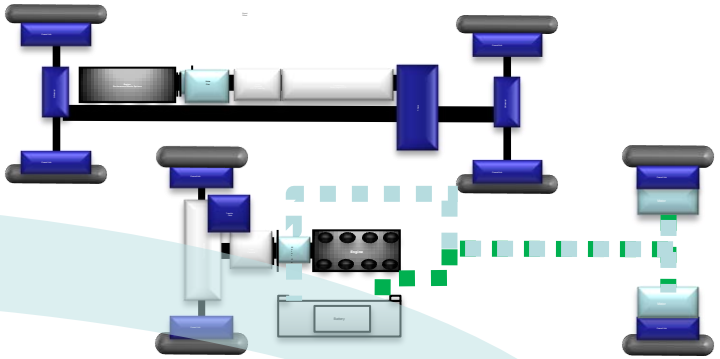
- Primary – Harford Loop Profile (paved)
- Secondary – Munson Standard Fuel Course Profile (paved/gravel)
- Trails – Churchville Test Area B- Course (dirt)

Additional Analysis Drive Cycles

- TARDEC Drive Cycles (Derived from HEVEA Duty Cycle Experiments)
  - Speed Traces (minimal elevation change)
  - Urban Assault Mission
  - Convoy Protection Mission

Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

Concepts/Proposals



Mission Profile

- Wartime xx/xx/xx Primary/Secondary/Trails
  - 20 Hour Duration; x hrs moving/ x hrs Idle
- Peacetime xx/xx/xx Primary/Secondary/Trails
  - 20 Hour Duration; x hrs moving/ x hr Idle

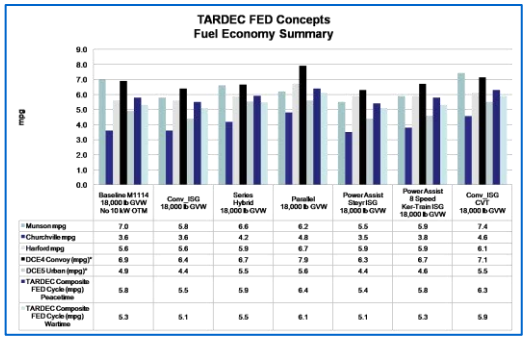
Component Sizing (Engine, Trans, Torque Converter, Driveline Motors, ISG, Battery)

Auxiliary Load

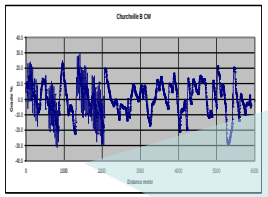
Cooling Requirements

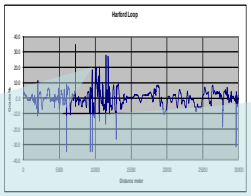
Drive Cycle Definition

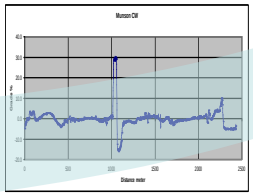
Analysis

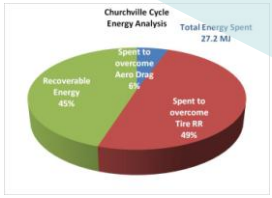


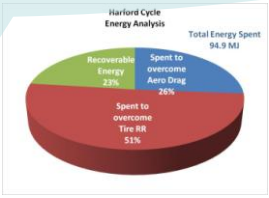
	Baseline M1114 18,000 lb GVW No 10 kW OTM	Conv_ISG 18,000 lb GVW	Series Hybrid 18,000 lb GVW	Parallel 18,000 lb GVW	Power Assist Steyr ISG 18,000 lb GVW	Power Assist 8 Speed Ker-Train ISG 18,000 lb GVW	Conv_ISG CVT 18,000 lb GVW
Munson mpg	7.0	5.8	6.6	6.2	5.5	5.9	7.4
Churchville mpg	3.6	3.6	4.2	4.8	3.5	3.8	4.6
Harford mpg	5.6	5.6	5.9	6.7	5.9	5.9	6.1
DCE4 Convoy (mpg)	6.9	6.4	6.7	7.9	6.3	6.7	7.1
DCES Urban (mpg)	4.9	4.4	5.5	5.6	4.4	4.6	5.5
TARDEC Composite FED Cycle (mpg) Peacetime	5.8	5.5	5.9	6.4	5.4	5.8	6.3
TARDEC Composite FED Cycle (mpg) Wartime	5.3	5.1	5.5	6.1	5.1	5.3	5.9

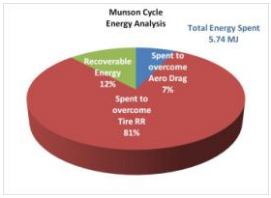




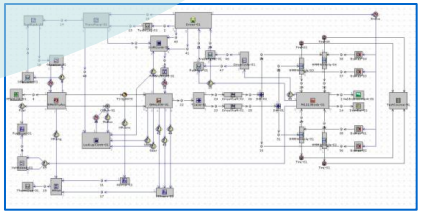








Model Builds



Army, Tank-Automotive RD&E Center, System Level Fuel Economy Analysis

Delta from Baseline 18,000 lb HMMWV No 10 kW OTM	Conv_ISG 18,000 lb GVW	Series Hybrid 18,000 lb GVW	Parallel 18,000 lb GVW	Power Assist ISG 18,000 lb GVW	Power Assist 8 Speed Binary Logic ISG 18,000 lb GVW	Conv_ISG CVT 18,000 lb GVW
	Team 1 Program	Team 2 Ideal	Team2 Program	Team 3 Ideal	Team 3 Program	
Munson mpg	-17%	-5%	-11%	-21%	-16%	6%
Churchville mpg	0%	16%	33%	-3%	6%	27%
Harford mpg	0%	5%	20%	5%	5%	9%
Idle Fuel Consumption (gal/hr)	-20%	-20%	-20%	-20%	-20%	-22%
DCE4 Convoy (mpg)*	-7%	-3%	14%	-9%	-3%	3%
DCE5 Urban (mpg)*	-10%	13%	14%	-10%	-6%	12%
TARDEC Composite FED Cycle (mpg) Peacetime	-5%	2%	10%	-7%	0%	9%
TARDEC Composite FED Cycle (ton-mpg) Peacetime	-5%	2%	10%	-7%	0%	9%
TARDEC Composite FED Cycle (mpg) Wartime	-4%	3%	15%	-4%	0%	11%
TARDEC Composite FED Cycle (ton-mpg) Wartime	-4%	3%	15%	-4%	0%	11%
Gal per Peacetime Cycle	5%	-2%	-9%	6%	0%	-8%
Total Fuel Consumed Peacetime (gal)	5%	-3%	-10%	5%	0%	-8%
Gal per Wartime Cycle	3%	-3%	-12%	4%	0%	-10%
Total Fuel Consumed Wartime (gal)	1%	-4%	-13%	2%	-2%	-11%
0-30 mph sec	33%	67%	40%	19%	45%	59%
0-50 mph sec	55%	75%	57%	48%	57%	62%
Top Speed mph	13%	5%	27%	-5%	7%	13%
5% Grade mph	67%	67%	79%	21%	72%	59%
60% Grade mph	100%	100%	100%	100%	100%	100%

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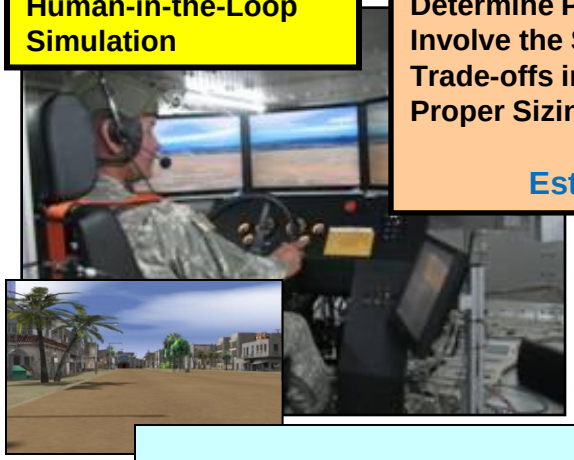
RDECOM

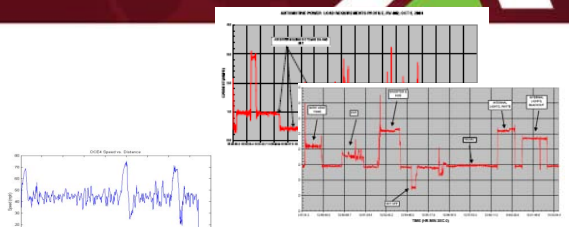
TARDEC

Human-in-the-Loop Simulation



Determine Proper Duty Cycles for Design
Involve the Soldier
Trade-offs in Mobility and Non-mobility Power Availability
Proper Sizing of Components

Establish Power Management Strategy

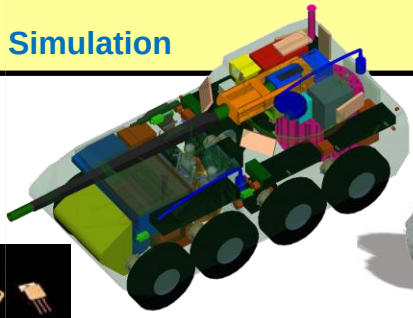


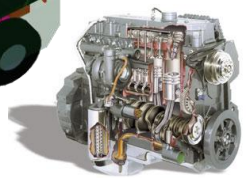
Drive Cycle Profiling M&S

Silent Watch Load Profile M&S

Requirements Capture, Concept Development
Mathematical Modeling, Data Analysis
High Performance Computing, Advanced Collaborative Environments

Integrated System-Level Simulation



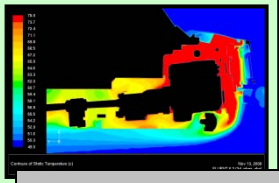


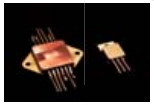
Advanced Power Management

METRICS: Rule Based – Table Lookup

Intelligent Power Management with Thermal Management Strategies

METRICS: Automated

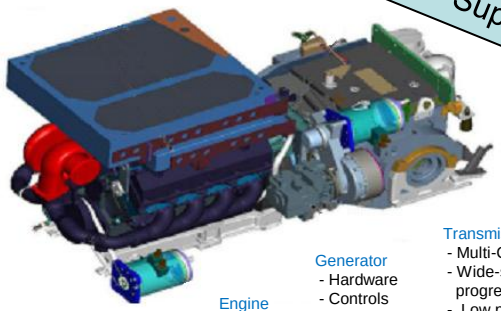




Up-Front M&S Supports P&E Tech Investments

Cognitive Power and Thermal Management Control Strategy

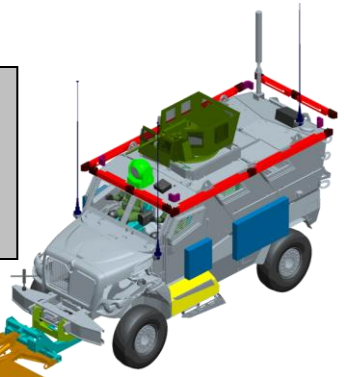
METRICS: Cognitive/Collaborative



Engine
- Multiple fuels
- Integrated Controls
- Noise abatement

Generator
- Hardware
- Controls

Transmission
- Multi-Cone clutches
- Wide-spread, equally progressive gear ratios
- Low parasitic oil mgmt.
- Variator technologies
- Integrated controls



Making the Army a Smarter Buyer

UNCLASSIFIED

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Summary

- Many Tools Available for Assessment of Military Vehicle Energy Usage
- Energy Usage Can be Accurately Assessed at the Platform Level
- BUT -
  - Data required for Assessment often difficult to obtain, especially in pre-system acquisition (*Some success in Technology Demo Phase of JLTV*)
  - Expected usage of vehicle most critical for accurate prediction (*difficult for Army vehicles*)
  - Advanced Powertrains – Control System Logic is key, but Proprietary

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